Appendix A

Statistics for the Interactive Calibration Program

Introduction

This appendix lists the statistics that are proposed to be included with the Interactive Calibration Program (ICP) and provides some of the rules to follow when specifying time series and computing statistical values. For some of the proposed statistics more details are provided regarding the input required, options to be included, and the form of the displays. Specifications with probably even more detail will be needed for each statistic that will eventually be included in ICP, however, until a commitment is made to add a graphical statistics package to ICP, an overview of such specifications are only warranted as a sample for a few of the statistics.

Rules for Time Series

Each statistical display added to ICP will involve one or more time series. Most of the statistics will involve a comparison of 2 time series, though some statistics could be designed for a single or multiple time series. Time Series that can be used by MCP/ICP are specified by an 8 character identifier, a 4 character data type, and a time interval that can evenly divide into 24 hours. Time series with more than one value per time interval (e.g. ROCL and SMZC) also need an 8 character keyword in order to specify which variable is to be used (e.g. see V.3.3-PLOT-TS of the NWSRFS User's Manual). For each data type certain information is specified (see chapter I.10 of the User's Manual). This includes the dimension associated with the data values, standard internal units (always metric), standard English and metric display units, and a time code. The time codes indicate the proper action to take when increasing the time interval of the data values (e.g. when going from an hourly to a 24 hour interval). The codes are INST (instantaneous values - pick off values at new interval), MEAN (mean data - average values over the new interval), and ACCM (accumulated value - sum the data over the new interval).

Since the proposed statistics package for ICP is designed for a wide variety of types of data, rules are needed as to which combination of time series are allowed. The proposed rules are:

1. Only time series with the following dimensions can be included: L (length), L3 (volume), L3/T (volume over time), and TEMP (temperature). There are 9 other dimension codes used currently by NWSRFS, however, time series with those dimensions are either seldom included in a calibration or are unlikely to need a statistical analysis.

2. All time series specified for a given statistic must have the same dimension and the same time code. The current time codes used for each allowed dimension are TEMP (INST and MEAN), L (INST, MEAN, and ACCM), L3 (ACCM and INST), and L3/T (INST).

3. The time interval of all subsequent time series specified for statistics involving more than

one time series must have a time interval that is an even multiple of the time interval of the initial time series (base series as specified in rule #1 in the next section titled "Rules for Statistics").

Rules for Statistics

The following rules are proposed for computing and displaying statistical information:

1. For statistics that involve multiple time series (typically the comparison of two time series) the first time series specified will be serve as the base series (generally the observed value time series when comparing simulated and observed data). For any comparison statistics the other time series will always be compared to the base series (e.g. differences will be computed as the subsequent time series minus the base series and ratios will be the subsequent time series divided by the base series).

2. The time interval used for the statistical computations and displays will be those associated with the base time series. If the other time series have a shorter time interval, the values will be converted to the time interval of the base series before doing any calculations. Other time series will not be allowed to have a longer time interval than the base time series.

3. Units for displays will be English or metric based on the value of the variable METRIC in the MCP /FENGMT/ common block (this value is based on the 5th input field on the A2 MCP3 input card - see section IV.4.4-MCP3 of the NWSRFS User's Manual). If metric units are specified, the display units are the standard FCST units for the data type. If English units are to be used, the units and conversion factors are those obtained via the FCONVT subroutine (see section IX.3.3B of the NWSRFS User's Manual). The units for each statistic will be determined from the standard units for the base time series. If the other time series have different standard units, the data will be converted to the units of the base time series.

4. One of the specifications for each data type is whether missing values are allowed in the time series. A time series for a data type that allows missing values might not contain any missing data, however, when missing values are encountered they will affect the statistical computations. The proposed general rules to follow for missing data are:

a. For statistics computations involving the comparison of two time series, only compute the statistical quantity when the values of both time series are non-missing. Thus, the number of cases will be the number of times that both series contain a non-missing value.

b. When totaling or averaging values, the total or mean is set to missing whenever any value involved in the computation is missing.

c. The number of missing values should be tabulated for each time series (based on the time interval used for the statistical computations, not the time interval of the time series), as well as the number of pairs of values used for statistical comparisons. Whenever

missing data are encountered during the calculations, the main display window for each statistic should contain a message indicating that missing values exist with an option to display a tabular summary of the missing data on a monthly and total period basis.

d. For accumulation plots, the values for missing periods should be estimated so that the plot can be generated even when missing values are encountered. The estimate should be the mean of all the non-missing values for the time series (the use of monthly means would be better than using the overall mean value). Estimated data periods should be shown in a different color on the graphical displays.

Proposed Statistics

There are many statistics that could be included in ICP. The most useful statistics for calibration are those that indicate trends or bias between simulated and observed quantities since one of the objectives of the calibration process is to remove trends and bias to the maximum extent possible. Statistics that show the time series properties are helpful when comparing simulations for different periods of time, such as comparing the calibration period results to independent validation periods. Goodness of fit statistics are mainly of use in comparing alternative models or methods. Statistics for individual time series can be useful to determine the appropriateness of model input and validation data and to spot large data errors. The list in this section is not meant to be all inclusive, but only to suggest a number of statistics that have been useful in the past to access model performance and which would be valuable to display in graphical form as part of the calibration process when using ICP. Following the list are more detailed specifications for a few of the statistics. These are meant to serve as a sample of some of the information that needs to be provided to whomever codes the statistical enhancement. A full set of descriptions will be needed when a commitment is made to actually add this feature to the program and the list of statistics to be included is finalized.

Statistics that should be considered for adding to ICP are as follows.

1. Seasonal Comparison - would involve comparing two time series on a monthly and annual basis. The main display would be a plot of the differences on a monthly basis. The difference plot could use percentages or absolute values. The annual difference would also be shown. Options would be to display plots of the monthly means, standard deviations, maximums, and minimums for each time series.

2. Magnitude Comparison - would involve comparing two time series at different levels of magnitude. There are several ways of displaying this information. A frequency exceedence plot could be used to compare the frequency of occurrence of different size values. These plots could be generated based on the entire data period or could be produced on a seasonal basis as shown in Part 7 of the NOAA video on “Calibration of the Sacramento Soil Moisture Accounting Model”. Percent differences in values for various magnitude intervals could be plotted. The intervals could be derived from the total period frequency plot based on certain exceedence values or input by the user.

3. Accumulation Comparison - would involve showing how the accumulated values of two time series compare over time. Such a comparison is needed to discover time trends that may exist due to data inconsistencies or changes in watershed characteristics, storm dynamics, or climate. The main display would show the accumulated difference between the time series versus time. Options would show the accumulation traces for each time series and the incremental difference on a monthly basis.

4. Peak Comparison - would involve comparing peak values above a specified amount. A window in time about each peak in the base time series would be analyzed. Histograms could show the distribution of the magnitudes of the base series peaks and the differences, in terms of both magnitude and timing, between the peaks for the two time series (similar to the histograms for high flows in Part 7 of the NOAA calibration video except that timing differences would also be shown). A scatter diagram of the peaks for the two time series could also be generated.

5. Event Comparison - would involve comparing two time series during a number of user specified time periods. Various quantities such as maximum and minimum values, event average (INST or MEAN types) or total (ACCM types), time of maximum, number of values above or below a user specified value, center of mass, etc. could be computed and compared graphically using histograms and scatter diagrams.

6. Exceedence Probability Comparison - would involve comparing two time series by generating displays similar to those produced for Ensemble Streamflow Predictions (ESP). The user would select a window of time and a variable to compare (max, min, cumulative value, average, or # cases above or below a specified value). The probability of exceedence would be computed and plotted against the range of values for the variable used. Such plots could be used to see how well the calibration was reproducing estimates of key forecast variables over periods of time when such forecasts are of importance.

7. Goodness of Fit Comparison - would involve comparing the similarity of two time series. A scatter diagram of one time series plotted against the other and the linear best fit line could be generated. Numerical values like the correlation coefficient, root mean squared (RMS) error of time interval values, RMS error of monthly totals or means, RMS errors divided by the appropriate mean, and the Nash-Sutcliffe criterion could be computed. Text summaries could be generated for all data values and graphics could illustrate how the statistics varied by month.

8. Individual Time Series Statistics - would involve statistical properties of individual time series. The number of time series analyzed at one time could vary (e.g. it might be useful to see statistics for model input series, such as precipitation and temperature, for multiple areas or zones on one plot). It could also be of value to compare the properties of streamflow data at several locations within a river basin. The graphical displays that could be produced include a frequency exceedence plot, seasonal (monthly) average and standard deviation plots, seasonal (monthly) maximum and minimum value plots (either max/min based on the

time interval of the data or max/min of the monthly total or average), and accumulated value versus time plots.

9. Autocorrelation Function Comparisons - would involve computing and graphically plotting the autocorrelation functions and residuals as shown in Part 7 of the NOAA calibration video.

Seasonal Comparison

Description: Generates plots showing how time series vary on a seasonal basis.

Number of Time Series: 2

Values Used: The comparisons are based on monthly values for each time series. The values used are monthly averages (INST or MEAN time codes) or monthly totals (ACCM time code) for the period of record for each time series and the monthly average of the difference between the mean or total for the two time series for each month. Also the standard deviation, maximum, and minimum of the monthly mean or total for each time series for each month would be needed when selected for display.

Options at Definition Time:

- Form of main graphical display (one plot must be included)
  - Percent difference plot (yes/no - default is yes except for time series with dimensions of TEMP - this option not valid for TEMP dimensions)
  - Absolute difference plot (yes/no - default is no except for TEMP dimensions) and units
    - Standard units for data type (default)
    - Runoff depth units in case of dimension=L3, time code=ACCM, std. units=CMSD

- Drainage area for L3, ACCM, CMSD data types when runoff depth units selected

Main Display: The display that is produced when this statistic is selected contains one or two plots of the monthly difference of the 2nd time series specified at definition time versus the base time series (i.e. 1st defined). The plots generated are those specified at definition time. Besides the season difference plots, the annual (total) difference will be shown as a dashed line across each plot.

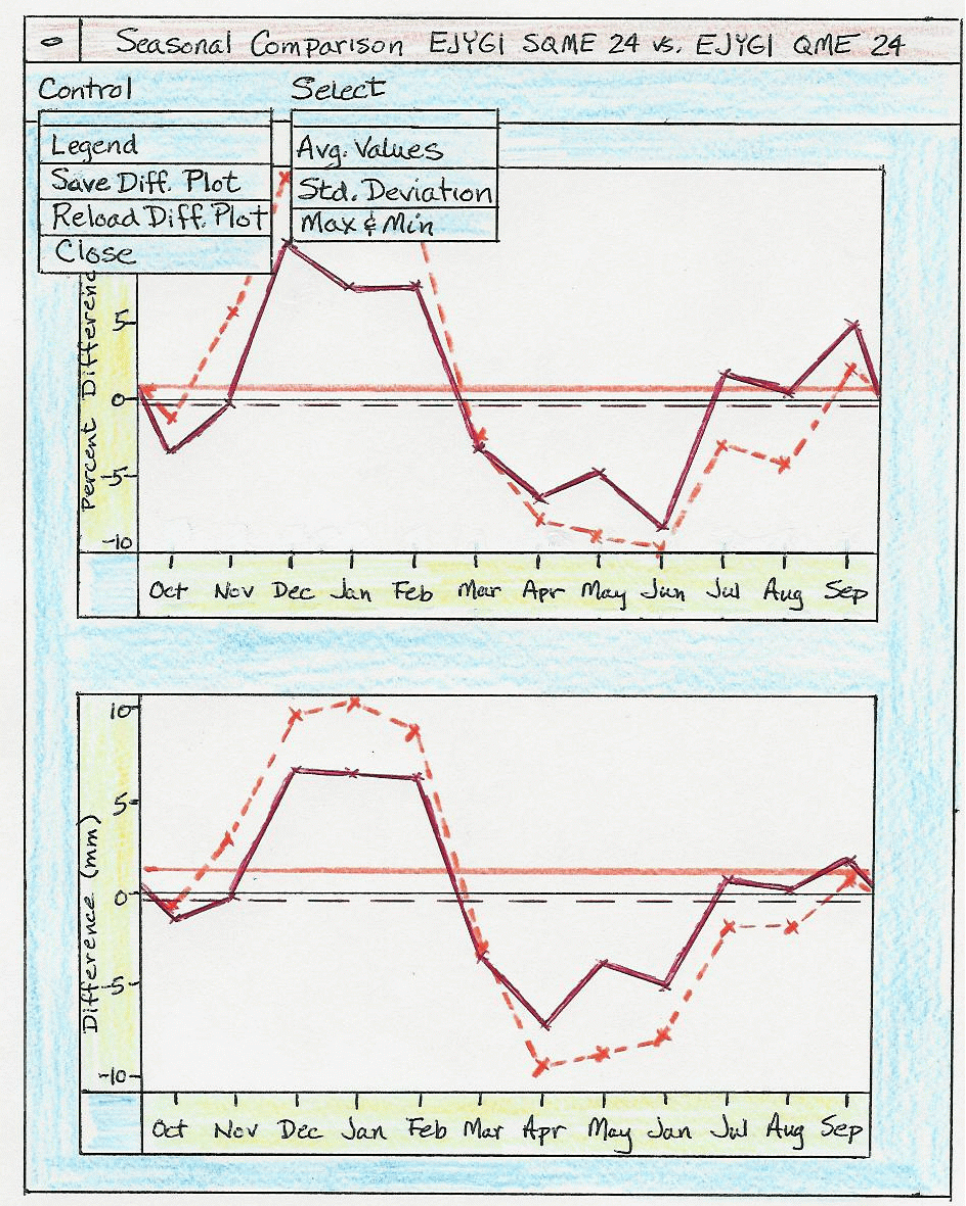
Options at Display Time:

- Options under the Control menu for the main display (in addition to Legend and Close)
  - Save Difference Plot - when selected, this option saves the monthly difference plot(s) for display latter.
  - Reload Difference Plot - when selected, this option reloads the monthly difference plot(s) previously saved. The monthly values will be shown as a dashed orange line similar to other ICP displays and the annual value as a solid orange line.

- Options under the Select menu for the main display (each plot will have a Close button)
  - Average Values - when selected, a new plot will be produced showing the average value of each time series on a monthly basis. The annual average (INST or MEAN) as a line across the plot or the annual total (ACCM) in text form will be shown for each time series in the same color as the monthly values

◦ Standard Deviation - when selected, a new plot will be generated showing the standard deviation of each time series on a monthly basis with the standard deviation of all values for each time series shown as a dashed line across the plot.
◦ Max and Min - when selected, a new plot will be produced showing the maximum and minimum values for each time series for each month. These are the maximum and minimum monthly mean or total for each time series as noted under the Values Used.

Depiction of Main Seasonal Display:



Magnitude Comparison

Description: Generates plots showing how time series vary based on the magnitude of the values.

Number of Time Series: 2

Values Used: Comparisons are based on values for each time series at the time interval of the base time series.

Options at Definition Time:

- Units for frequency exceedence plot if dimension=L3, time code=ACCM, std. units=CMSD
  - Standard units (default)
  - Runoff depth units - if selected, drainage area must be input.

- Method of determining intervals for percent difference versus magnitude plot.
  - Compute 10 intervals based on the frequency exceedence plot for the base time series using exceedence levels of 0.1, 0.5, 2, 5, 10, 25, 50, 75, and 90 percent (default)
  - User specified (max of 10 intervals)
    - Number of intervals (N)
    - Values separating intervals (N-1 values)
      - Standard units for data type (default)
      - Frequency exceedence plot percent values for base time series

- Period to be used for the optional seasonal display if User Specified is chosen (if nothing input, this option will be grayed out for the Seasonal Analysis options under the Select menu of the main display. Input as beginning month and day and ending month and day.

Main Display: Two plots will be included in the main display window for the magnitude comparison. The first plot will be a frequency of exceedence plot showing the distribution for each time series. The second will be a plot showing the average percent difference between the time series for up to 10 magnitude intervals. The value of the base time series determines the interval assignment of each data value. The average percent differences are computed as the mean for the second time series specified minus the mean for the base time series divided by the mean for the base time series. The magnitude scale for the second plot should be divided to correspond to the number of intervals used with the limit for each interval shown on the scale. The number of cases for each interval should be tabulated.

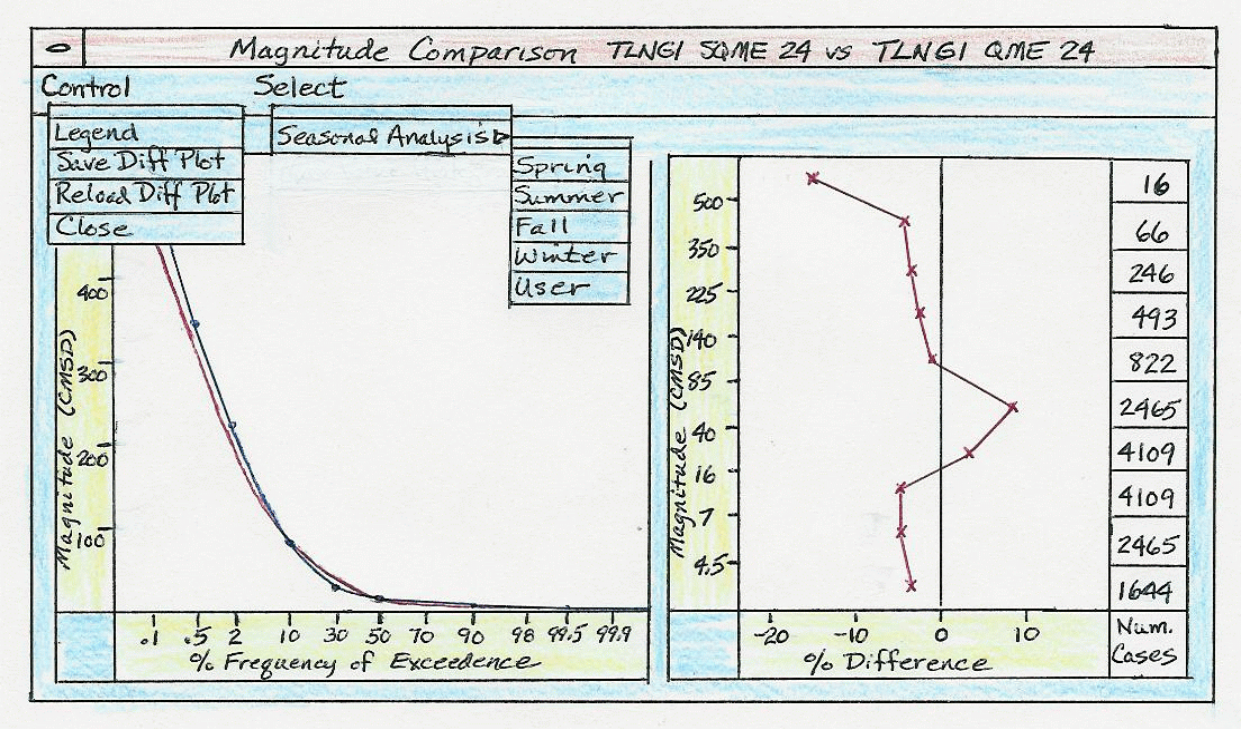
Options at Display Time:

- Options under the Control menu for the main display (in addition to Legend and Close)
  - Save Difference Plot - when selected, this option saves the average percent difference plot for display later.
  - Reload Difference Plot - when selected, this option reloads the average percent

difference plot previously saved. The previously saved plot will be shown in a dashed orange line similar to other ICP displays. A check will be required to make sure that the specifications of the intervals haven't changed since the plot was saved.

- Option under the Select menu for the main display (plot will have a Close button)
  - Seasonal Analysis - when selected, the user will be presented with options of Spring, Summer, Fall, Winter, and User Specified. After choosing one of these options, a new plot window will show the two magnitude plots (i.e. frequency of exceedence and interval difference) based only on data for the specified season. If another season is selected, the plots will be regenerated for the new season in the same window. There will be no option to save and reload the percent difference plot for these displays.

Depiction of Main Magnitude Display:



Accumulation Comparison

Description: Generates plots showing the comparison of how the time series values accumulate over time.

Number of Time Series: 2

Values Used: The accumulated amounts used for the comparison are computed from monthly values for each time series. The values used are monthly averages (INST or MEAN time codes) or monthly totals (ACCM time code) for the period of record for each time series.

Options at Definition Time:

- Units for plots if dimension=L3, time code=ACCM, std. units=CMSD
  - Runoff depth units - (default) - drainage area must be input.
  - Standard units for data type

Main Display: The display that is produced when the accumulation statistic is selected is a plot of the accumulated difference between the two time series. This is the accumulated value of the second time series specified minus the accumulated value for the base time series versus time.

Options at Display Time:

- Options under the Control menu for the main display (in addition to Legend and Close)

  - Save Difference Plot - when selected, this option saves the accumulated difference plot for display later.

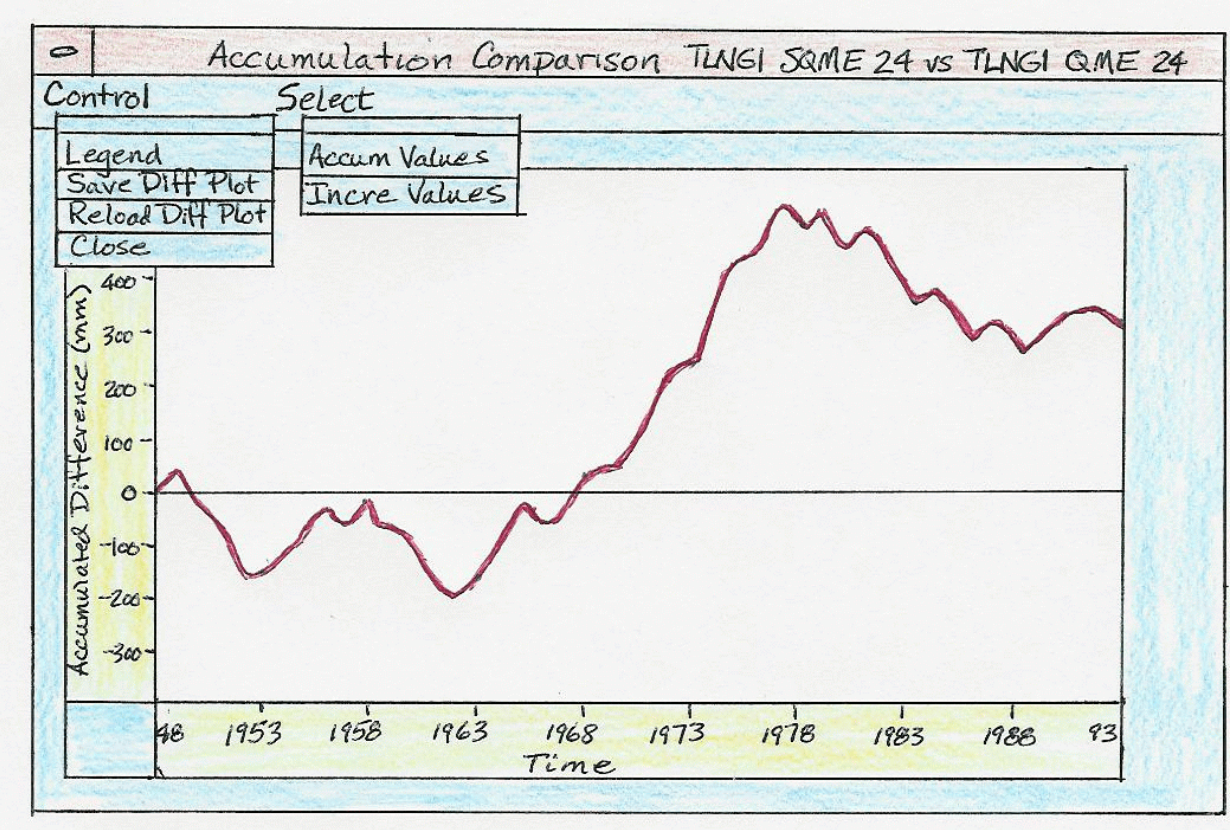
  - Reload Difference Plot - when selected, this option reloads the accumulated difference plot previously saved. The previously saved plot will be shown in a dashed orange line similar to other ICP displays.

- Options under the Select menu for the main display (each plot will have a Close button)

  - Accumulated Values - when selected, a plot with the accumulated value of each time series versus time will be generated.

  - Incremental Values - when selected, a bar chart showing the incremental difference between the second time series and the base for each month will be generated.

Depiction of the Main Accumulation Display:



Individual Time Series Statistics

Description: Generates various plots showing statistical properties of one or more time series.

Time Series: One or more

Values Used: Both values at the time interval of the base time series and monthly values will be used. Monthly values are averages (INST or MEAN time codes) or monthly totals (ACCM time code) depending on the time code associated with the time series.

Options at Definition Time:

- Units for plots if dimension=L3, time code=ACCM, std. units=CMSD
  - Runoff depth units - (default) - drainage area must be input.
  - Standard units for data type

Main Display: The following plots will be generated when the Individual Time Series Statistics option is selected (the values for all time series will be shown on each of the plots):

- Frequency exceedence plot of values at the base time interval

- Seasonal (monthly) average values (annual average (INST or MEAN) shown as a dashed line across the plot or average annual total (ACCM) shown in text form in the same color as used for the time series)

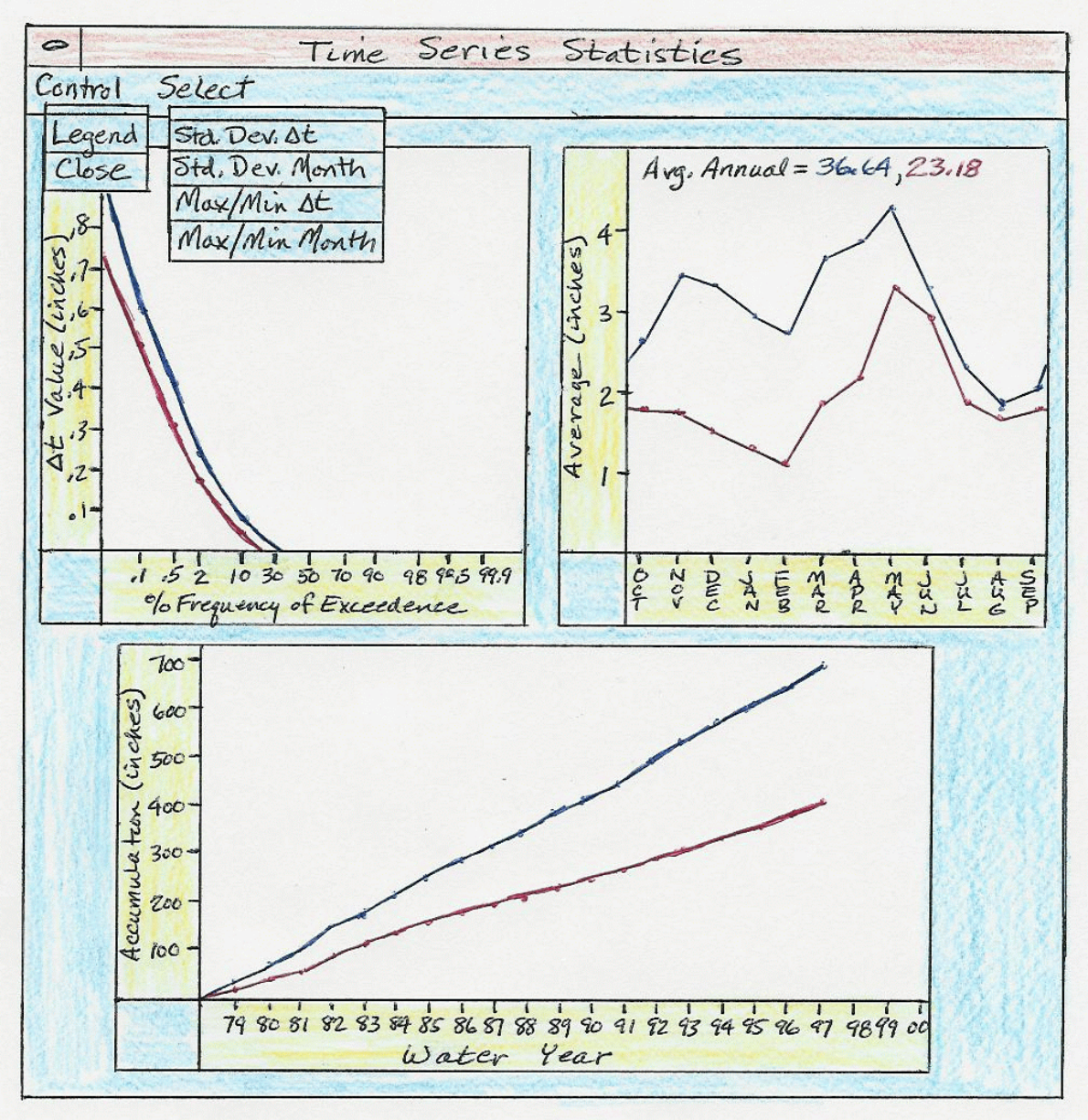
- Accumulated value plot

Options at Display Time:

- Legend and Close will be the only options under the main display Control menu

- Options under the Select menu of the main display (each new plot will have a Close button)
  - Standard Deviation Δt - a plot of the standard deviation of the individual time interval values for each month will be generated showing values for all time series (standard deviation of all values shown as a dashed line across the plot in the same color as used for the time series)
  - Standard Deviation Month - the standard deviation of the average or total monthly values will be added to the seasonal average value plot for each time series as a dash line in the same color as used for the time series.
  - Max/Min Δt - a plot of the maximum and minimum of the individual time interval values for each month for each time series will be produced.
  - Max/Min Month - a plot of the maximum and minimum of the average or total monthly values for each time series will be generated.

Depiction of the Main Individual Time Series Statistics Display:


Time Series Statistics
Control
Select
Legend
Close
Std. Dev. Δt
Std. Dev. Month
Max/Min Δt
Max/Min Month
Δt Value (inches)
% Frequency of Exceedence
Avg. Annual = 36.64, 23.18
Average (inches)
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Accumulation (inches)
Water Year